# Coastal Benthic Optical Properties (CoBOP): Optical Properties of Benthic Marine Organisms and Substrates


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## LONG-TERM GOAL

The long-term goal of this research is to gain an understanding of the nature and significance of fluorescence and reflectance characteristics of benthic marine organisms in general, and coral reef cnidarians in particular. We wish to determine both how biological processes act to determine the optical properties and how optical measurements can be used to provide insight into biological state or process.

## OBJECTIVES

There were several objectives for this year's work:

- Make *in situ* measurements of fluorescence and reflectance spectra of benthic marine organisms and substrates in support of our own research and that of collaborators in the Coastal Benthic Optical Properties (CoBOP) research program;
- Conduct ground truth for the Naval Research Laboratory's Portable Hyperspectral Imager for Low Light Spectroscopy (PHILLS): target identification, video documentation, and measurement of reflected light spectra;
- Collect baseline fluorescence excitation/emission spectra for the coral fluorescent pigments;
- Compare reflectance data with data from other researchers using related instrumentation.

## APPROACH

This work is part of the Coastal Benthic Optical Properties (CoBOP) program. The main effort in FY99 was conducted as part of the CoBOP field campaign at the Caribbean Marine Research Center, Lee Stocking Island, Bahamas. The work described here was carried out by Charles Mazel (Physical Sciences Inc.) and Eran Fux (doctoral candidate, Department of Ocean Engineering, MIT).

*In situ* measurements of fluorescence and reflectance were made with the DiveSpec, a new diver-operated instrument for measurement of spectral signatures from discrete benthic features. Laboratory measurements of fluorescence excitation and emission spectra were made with a FluoroMax-2 spectrofluorometer. Site documentation was done by visual inspection and videotape recording.

# Report Documentation Page

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**WORK COMPLETED**

We participated in the CoBOP field campaigns in January and May/June 1999. Over 450 individual measurements were acquired with the DiveSpec in 13 dives. The data include reflectance factor, spectral signature, and fluorescence measurements. We collected sediment reflectance data at all of the primary sample sites selected by the sediment group. We collected the data for 3D excitation/ emission matrix spectra from over 30 coral and sediment samples.

We continued measurement and modeling work on the contribution of fluorescence to the apparent reflectance of seafloor features. Using Hydrolight 4.0 in combination with field data we modeled the contribution of fluorescence to spectral signature as a function of depth, sun angle, and fluorescence efficiency. The signatures were further analyzed to determine the change in chromaticity coordinates (apparent color to a human observer) that accompanied the spectral shifts. A working document on the results was presented at the 1999 ASLO meeting.

We made additional presentations of CoBOP-related work at the Ocean Optics XIV conference in November 1998 and the National Coral Reef Initiative Conference in April 1999 (see References).

**RESULTS**

Figure 1 is a summary of sediment reflectance data from the primary sampling sites. These spectra are currently being compared with data from the same location taken by other CoBOP researchers who are measuring reflectance with different instruments.

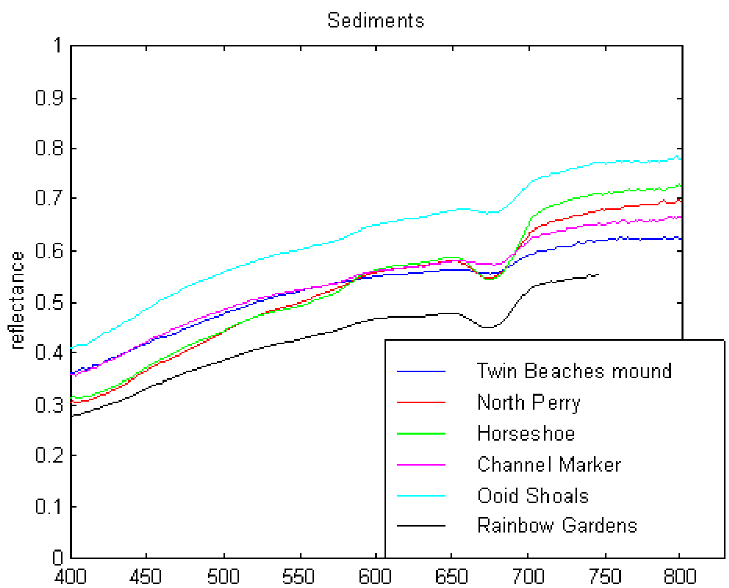
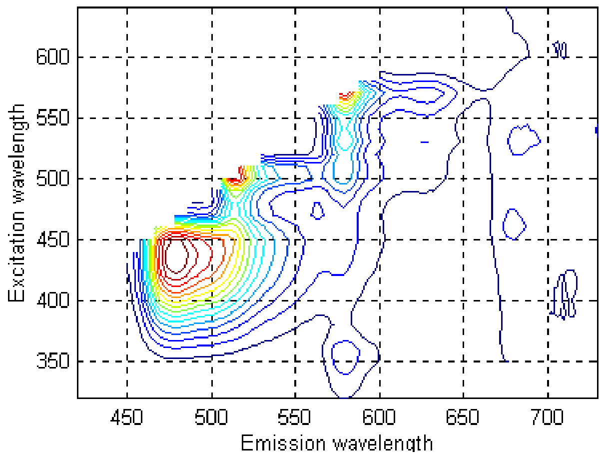



***Figure 1. Summary graph of sediment reflectance data at the primary sample sites. All curves are means of multiple spectra.***

The 3D fluorescence excitation/emission matrix spectra (Figure 2) aid in characterizing the various sources of fluorescence found in the field. During the course of this work we (in collaboration with Maxim Gorbunov, Rutgers) documented a new fluorescence signature that had not previously been observed in Caribbean corals (Mazel, 1997).



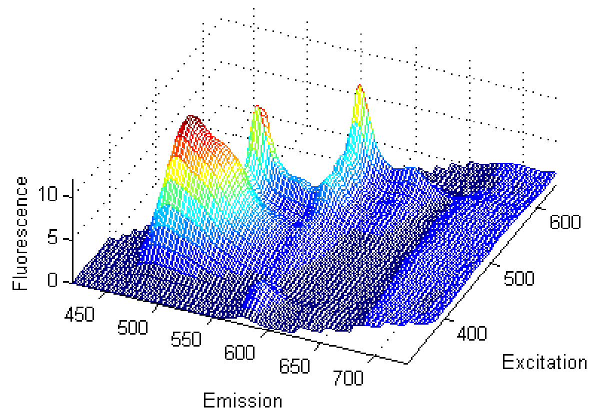




*Figure 2. 3D excitation/emission spectrum for a specimen of the coral* **Montastraea cavernosa.** *Contour plot (left) and 3D surface plot.*

Figure 3 is an example of the kind of data that was collected both to characterize coral optical properties and in support of PHILLS hyperspectral imagery interpretation. Spectra of reflected light were collected from several distances from targets such as these to 'follow' the upwelling light toward the water surface.

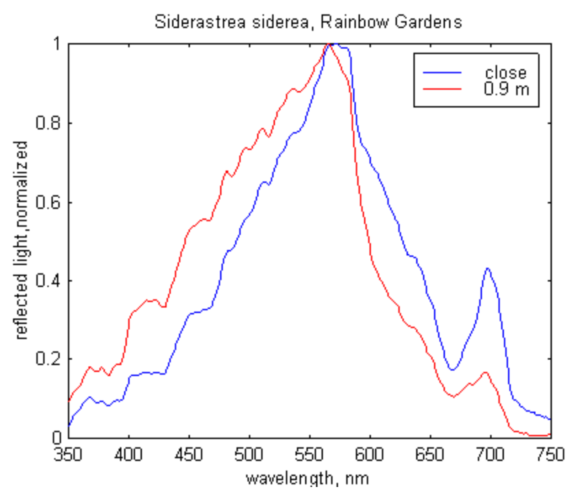
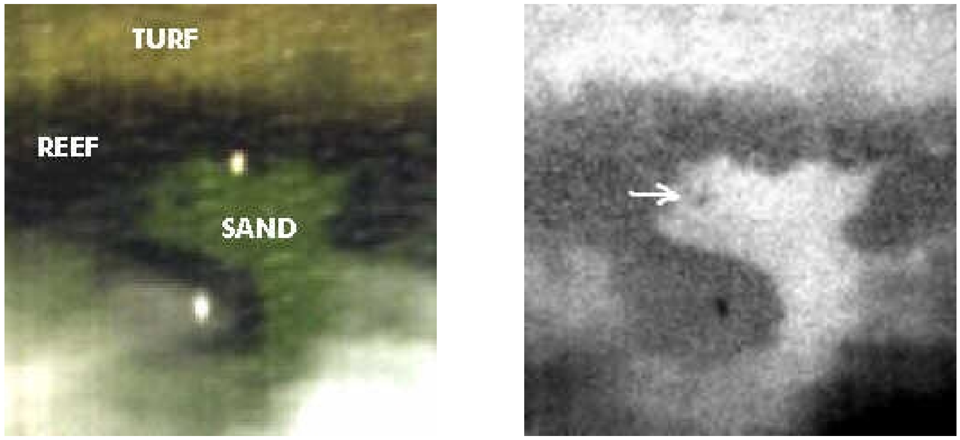



*Figure 3. Frame-grabbed video image of the coral* **Siderastrea siderea** *(left), and upwelled light spectra measured at distances of 10 cm (close) and 0.9 m. The spectra have been normalized to emphasize the differences in spectral shape.*

Figure 4 shows how this kind of data is being applied to PHILLS imagery interpretation. The image on the left (4A) is a false-color RGB made using PHILLS bands 19 (555.2 nm), 11 (481.8 nm), and 4 (417.5 nm) for the red, green, and blue channels, respectively. There are three main bottom types evident – reef, sand, and turf. Some clouds are also present in the image. Both the PHILLS data and in situ data were used to select these bands. Using the Band Math algorithms in ENVI, we computed the ratio of band 11 to 4, displayed as Figure 4B. The reef and sand are well delineated, and the light and dark banding of the water over the sand, due to waves, has disappeared. The small feature indicated by the arrow in 4B was confirmed to be a reef structure surrounded by sand. Note that in 4B

the area marked as turf appears similar to the sand. A different set of wavelength bands can be used to separate this region.




***(A) (B)***

***Figure 4. Pseudocolor PHILLS image (A) and band-math classified image (B) of the Horseshoe Reef area.***

Figure 5 is an illustration of the effort to investigate the influence of fluorescence on apparent reflectance. The blue line is data measured from an orange-fluorescent specimen of *Scolymia* sp. at a depth of 18 m. The red line (modeled data) was constructed by starting with the reflectance spectrum of a non-fluorescent coral and a downwelling irradiance spectrum calculated with Hydrolight using field measurements for water optical properties. We then added orange-fluorescent pigment at 7% fluorescence efficiency and chlorophyll fluorescence at 0.8% efficiency (both reasonable values based on past measurements). The agreement is excellent, and the technique may permit us to estimate efficiencies based solely on field measurements.

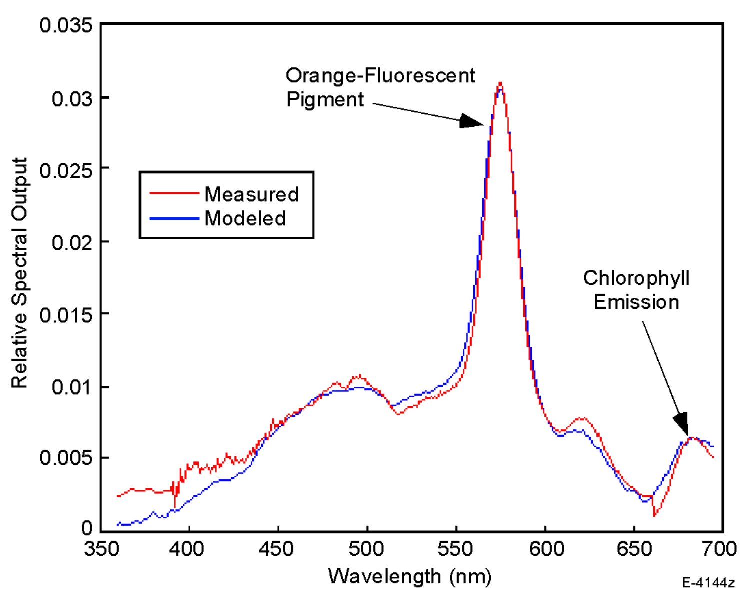



***Figure 5. Comparison of measured (blue) and modeled (red) data for the spectrum of light leaving the surface of a coral with orange-fluorescent pigment at a depth of 18 m.***

## IMPACT/APPLICATION

The measurements of benthic spectral properties will contribute to understanding of the relation between biology and optics. They will also assist in the effort to use optical remote sensing to probe benthic biological systems and will be used in radiative transfer modeling.

## TRANSITIONS

Spectral measurements of sediment reflectance are being used by members of the CoBOP sediment group as part of their work in correlating sediment properties and sediment optics. Reflectance data from various substrates are being used by Curt Mobley as endmembers for radiative transfer modeling with Hydrolight. The spectral signature data will be used by the NRL group in PHILLS data interpretation.

## RELATED PROJECTS

I am working on an ONR project to develop an improved version of a diver-operated spectral measurement instrument for more general use by CoBOP collaborators and other researchers.

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